



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>



*The anatomy and some of the
biological aspects of the ...*

Harlan Harvey York



3 2044 107 239 436

MT
67
Y9
LIBRARY OF THE GRAY HERBARIUM
HARVARD UNIVERSITY.
THE GIFT OF
B. L. Robinson

BULLETIN
OF THE
UNIVERSITY OF TEXAS

NUMBER 120

ISSUED SEMI-MONTHLY

SCIENTIFIC SERIES, NO. 13

MARCH 15, 1909

*The Anatomy and Some of the Bio-
logical Aspects of the "Amer-
ican Mistletoe"*

Phoradendron Flavescens (Pursh) Nutt.

BY

HARLAN H. YORK

Instructor in Botany



Entered as second-class mail matter at the postoffice at Austin

AUSTIN, TEXAS

CONTENTS

Introduction.....	5
The seed.....	5
Dissemination of the seeds.....	7
Germination.....	8
Formation of aerial shoots.....	9
Rate of growth.....	9
Period of growth.....	10
The mature plant.....	10
The leaf.....	10
The stem.....	12
Cortex.....	12
The xylem.....	13
The cambium.....	14
The pith.....	14
The medullary rays.....	14
The haustoria.....	15
The sinkers.....	17
Aerial haustoria.....	19
Effect of the mistletoe upon its host.....	20
Remedies and means of eradication.....	24
Summary and conclusions.....	25
Literature cited.....	27
Explanation of plates.....	27

THE ANATOMY AND SOME OF THE BIOLOGICAL ASPECTS OF THE "AMERICAN MISTLETOE," PHORADENDRON FLAVESCENS (PURSH) NUTT

BY HARLAN H. YORK

INTRODUCTION

According to the Engler and Prantl System of classification, there are eleven species of *Phoradendron* found in North America. Of these, five occur within the State of Texas, namely: *Phoradendron Bolleanum* Eichler and *Phoradendron juniperanum* Engelm., which are limited to various species of *Juniperus*, are reported from the western part of the State in the region of the Guadalupe Mountains and Howard Springs; *Phoradendron villosum* Nutt. is found in western and northwestern Texas; *Phoradendron californicum* Nutt. occurs in the vicinity of Eagle Pass; *Phoradendron flavescens* (Pursh) Nutt., which is the subject of this study, is distributed over the State as far west as Eagle Pass. It is commonly known as the "American Mistletoe" and, though it is distinctly southern in its range, it extends as far northward as southern New Jersey, Maryland, Ohio, Indiana and Missouri.

THE SEED

The seeds are usually matured by the last of November. In shape, they are flattened, oval to oblong and occur singly in white berries which are borne on short axillary spikes. The embryo is distinctly dicotyledonous and is almost entirely embedded in the endosperm. (Figs. 1 and 2.) It is abundantly supplied with chlorophyll. The cells in the free or radicle portion are rich in starch while in the part surrounded by the endosperm, there is very little starch present. The cotyledons are in such close contact with the endosperm, that it often appears as though there is but a single wall intervening between them and the cells of the endosperm (Fig. 3). The walls of the latter are thick while the adjacent cells of the cotyledons are thin-walled. These cells, which stain yellow with iodine, contain a fine granular substance

and numerous plastids which are well supplied with chlorophyll (Fig. 4). In the hypocotyl and radicle, the cells are larger and thicker walled than in the cotyledons and contain an abundance of starch (Fig. 5.) The endosperm is composed of large pitted cells. The cells of the outermost layer are palisade in shape. Their external walls have a distinct cuticular thickening while their radial walls are thin and have few pits (Fig. 3, b). Towards the embryo the cells become slightly thicker walled and more abundantly pitted. The cells adjacent to the embryo are very much smaller than those in other portions of the endosperm. The outer layers of cells in the endosperm are richly supplied with chlorophyll and contain small quantities of starch. The chlorophyll content of the endosperm gradually diminishes towards the embryo while the cells become more abundantly supplied with starch. Thus the embryo is well provided with food material for its immediate use on germination. Owing to the nature of its habitat, a period of time must elapse between germination and the establishment of the young plant on its host, when the ready food supply in the endosperm is likely to become exhausted. The purpose of the chlorophyll in the endosperm is evidently for photosynthetic work in order that the young plant may be supplied with food until it becomes fixed upon its host. The cotyledons may remain imbedded in the endosperm for a year or more and throughout the first year's growth of the plant, the peripheral cells of the endosperm are well supplied with chlorophyll. Thus besides a storage of food in the endosperm there is a mechanism whereby more food may be provided for the young plant after the stored-up supply becomes exhausted. Immediately surrounding the endosperm is a whitish coat, the testa, which is composed of elongated scalariform-like cells (Fig. 3, c). The testa is prolonged into a beak-like extension at the chalazal end of the seed and extends almost to the outer surface of the berry (Figs. 1 and 6). The seed is surrounded by a layer of semi-transparent substance, the viscin, which is structureless and varies from three to four mm. in thickness. It is of special importance in seed distribution since it glues the seeds firmly to the object on which they chance to fall. The firm attachment of the seeds by the viscin is of great importance in that they are not easily dislodged by the wind and rain, and also the

seedling can press the tip of the radicle more firmly against the substratum while establishing itself upon its host. The viscin is of a sweetish taste, which is doubtless one of the reasons why the berries are eaten so freely by birds. A thin semi-transparent cuticular-like coat surrounds the viscin and forms the outer covering of the berry.

DISSEMINATION OF THE SEEDS

The seeds are distributed almost entirely as a result of being eaten by birds. On account of the stickiness of the seeds, they may adhere to the beaks and feet of birds and later become dislodged. The principal birds in the vicinity of Austin which feed upon the berries are mocking birds, sparrows and cardinals. In his observations on the germination of *Phoradendron villosum* and *Phoradendron californicum*, Cannon¹ states the following: "The distribution of the mistletoe from tree to tree is likely always effected by the agency of birds, but its distribution in a tree may be brought about in another manner also, and thus it is frequently accounted for by the position of the older plant. In cases where infection has occurred on the higher branches of the host it frequently happens that numerous younger plants of the parasite will be placed directly under this pioneer, as if they were derived from seed." As far as the writer's observations have gone, a great number of young plants may often be found near an old plant as stated above, but besides being below an old plant, they often occur in the branches around it. From what the author has stated, we are led to infer that the seeds from which the plants below the old plant have developed, were not distributed by birds, but by accident as a result of lodging upon the twigs. The berries when ripe are rather turgid and have a firm outer covering. Hence, in falling, they will very seldom become broken, so that they will lodge upon the twigs. Thus it seems that the distribution of the young plants, below the old "pioneers" is almost entirely due to birds. That this is true, the writer is led further to believe from observations which were made upon birds while they were feeding on the berries.

GERMINATION

The seeds do not begin to germinate until they are exposed to favorable conditions of moisture and temperature. In this vicinity, germination begins about the middle of February and continues through March and April. It has been claimed that the seeds will not germinate unless they have passed through the alimentary canal of birds as a result of which the greater portion of the viscin is removed. A number of experiments were tried in germinating seeds without removing the viscin and the seeds germinated as readily as those which had been eaten by birds. Immediately on germination, the radical turns towards its substratum with which it comes in contact in a week to sixty days. This period of time, however, depends upon the conditions of moisture, temperature, and the position of the seed with reference to its substratum. As soon as germination begins the radicle enlarges slightly and becomes somewhat rounded at the end. On coming in contact with its host, it flattens out, forming a circular-like attachment disc (Figs. 7, 8, and 9). The shape of the disc, however, depends somewhat upon the character of the surface with which it comes in contact. Soon after reaching the substratum, a papilla-like projection, the primary haustorium, develops from the under surface of the attachment disc, which by mechanical force and the secretion of a digestive substance sinks itself into the bark of the host. At first the growth of the primary haustorium, as well as the whole plant, is exceedingly slow. As soon as the primary haustorium becomes established, it spreads out in the cork cambium, but does not penetrate beyond it (Figs. 10 and 11, a). Its direction of greatest growth is usually towards the distal end of the branch and with continued growth gradually encircles the branch. During the first year's growth, sinkers may be formed, and they usually penetrate the cortex of the host to the wood (Fig. 11, b). However, their formation during the growth of the first year depends upon the early germination of the seeds, as well as conditions of moisture and temperature. A number of examples were found in which the sinkers were not formed during the first year. Such an example is seen in Fig. 10, which is from a seedling that germinated about April 1, 1908. The cotyledons often remain imbedded in the old endosperm tissue until the young

plant is established on its host. They evidently function as absorbing organs to supply the young plant with food from the endosperm. The remains of the old endosperm tissue may persist for a year or more, adhering to the cotyledons (Figs. 8, c; 10, d; 12, a). The cotyledons may either wither after the young plant is fixed upon its host or become slightly enlarged. No examples were found where they had developed to form foliage leaves.

FORMATION OF AERIAL SHOOTS

The aerial shoots which are first formed usually arise from buds, which develop on the attachment disc (Fig. 13). Occasionally more than one shoot may arise from a single disc. Sometimes a shoot may develop from the plumule between the cotyledons (Fig. 12). Later as the haustorium spreads out in the cortex, buds are formed on its upper surface which develop into aerial branches.

RATE OF GROWTH

The rate of growth in the young plant is comparatively slow. The first year's growth has been discussed. During the second year the first foliage leaves are formed. Usually but a single pair is produced and the entire plant seldom reaches a length of more than 1.5 cm. by the end of the year (Fig. 14). During the third year a second pair of leaves is usually developed and the plants average from 2.5 to 3 cm. in height (Fig. 12). Figure 15 represents a plant about four years of age. Other stages of growth are represented in Figs 43, 44, and 45. The rate of growth is not uniform for all plants, the cause of which is probably due to the physiological activities of the host, the position and location of the parasite on its host, and various environmental factors, such as light, temperature and moisture. The rates of growth represented in Figs. 10, 12, and 14, have been determined by observation, and in Figs. 13, 15, 43, 44, and 45, the different ages were determined by noting the depth to which the sinkers were imbedded in the wood in relation to the annual rings. In some cases it seems that aerial shoots are not always formed at the beginning of the second year's growth. Figure 13 represents a section through a plant which was at least two years old, since the

sinker was imbedded to the depth of one annual ring, and in Figure 19 we have another example where the sinkers penetrate to the depth of two annual rings and only a single pair of foliage leaves have been formed.

PERIOD OF GROWTH

The period of growth evidently coincides with that of the host, the maximum growth being in the spring. Growth may continue throughout the whole summer. When aerial shoots were broken off at the outer surface of the bark of the host as late as August 15th new shoots were immediately sent up, which became over three centimeters in height by the middle of November.

THE MATURE PLANT

The mature plants are rather bushy in appearance and may reach a length varying from one to three feet (Figs. 46 and 47). The stems are round and have oppositely arranged branches. The leaves are in opposite pairs. The stems, like the leaves, are well supplied with chlorophyll, and, at a distance, the plants appear slightly yellowish green, especially during the winter months. The plants are dioecious. The flowers develop during late summer and fall and begin blooming about the first of December. It is not possible to determine accurately the age which the mistletoe may attain. By counting the annual rings of the host to the depth to which the sinkers are imbedded, it is possible to determine approximately the age of the mistletoe. The plant represented in Figure 20 was three feet in length and appeared to be at least twenty years of age. This is the oldest plant which the writer has observed. Kerner and Oliver² observed sinkers of the "European mistletoe," *Viscum album*, 10 cm. in length and inclosed in forty annual rings.

THE LEAF

The leaves vary in form from oblong-spatulate to oblong-ovate or orbicular, entire, rounded at the apex, narrowed at the base to a short petiole and obscurely three to five nerved. They are two and one-half cm. in length, from one and one-half cm. in width, and .8 to 1 mm. in thickness. They do not attain their complete

size in less than two or three years. The young leaves are slightly hairy but become glabrous at maturity. The position and structure of the leaves are much the same as has been described for *Phoradendron villosum*.³ At first the upper surfaces of the young leaves closely face each other, but later they come to occupy a more or less horizontal position, the blades and petioles often becoming variously bent, so that both sides are equally exposed to the light. In the young leaves the epidermis is well defined and of equal thickness on both sides. The outer walls of the epidermal cells are cutinized, and the cells in the mesophyll are more or less cubical in shape with small intercellular spaces (Fig. 17). As growth of the leaf continues the outer mesophyll cells of both surfaces become greatly elongated and palisade-like, while in the middle region of the mesophyll they enlarge more or less equally in all directions and many of them contain large rosette crystals of calcium oxalate (Fig. 18). The outer walls of the epidermis become more heavily cutinized. The yellow appearance of the leaves, as well as of the stem, is due to the presence of a yellow coloring substance in the external epidermal walls. The walls of the mesophyll cells are thin and become more or less pitted, and are well supplied with chloroplasts (Fig. 19). Stomata are equally abundant on both sides of the leaf and there are about twenty-seven to every square mm. They are of a xerophytic type and are not sunken beneath the surface as in the case of *Phoradendron villosum* (Figs. 20 and 21). In size and number, as compared with the stomata of the host, they are about the same as in case of *Phoradendron villosum* and its host; i. e., the stomata are about twice as large and half as many in a given area as compared with its host. The vascular system of the leaf is well developed. The ends of the leaf traces of the tracheids are slightly swollen and form water storage tracheids. These terminate in groups of mucilaginous cells with which they form water storage reservoirs (Figs. 22 and 23). The mucilaginous cells are large, their walls are often broken down or disintegrated and they are usually filled with a mucilaginous substance. The water storage areas increase in size by the contents of the adjacent cells, becoming replaced by mucilaginous substances which are often deposited in layers, giving the cell a stratified appearance (Fig. 23, c). Very often many of the cells adjacent to the water storage areas contain crystals of calcium

oxalate (Figs. 24, and 25). Since the reservoirs occur at the terminals of the tracheids, very few, as a rule, are near the larger veins. They are most abundant near the margin of the leaf and entirely absent from the base (Fig. 26). Cannon states that no water reservoirs are present in the leaves of *Phoradendron villosum*. The same occur in *Loranthus*, and have been described in *Viscum* by Marktanner-Turneretscher,⁴ and their presence was later denied by Solereder.⁵ At first they were not recognized in *Phoradendron flavescens*. They were first noticed in a leaf that had been cleared in a saturated solution of chloral hydrate. By this process the water storage reservoirs and connecting veins were made to stand out very prominently (Fig. 22). It is very probable that water storage reservoirs do occur in *Phoradendron villosum* and also in other North American species of *Phoradendron*.

THE STEM

The structure of the stem is quite like that which has been described for *Phoradendron villosum*. In general, it is the same as an ordinary woody dicotyledonous stem consisting of a vascular system, medullary rays, wood fibres, tracheary cells, and a central pith region.

CORTEX

The young epidermal cells and the cortical cells just beneath are somewhat cubical or slightly elongated in shape, but become flattened as the stem grows older. In the epidermis, the outer walls are cutinized, while the radial walls are slightly pitted. The stomata are sunken beneath the outer surface (Fig. 27). As the stems grow older, the outer walls of the epidermis become heavily cutinized and the radial walls distinctly pitted. The stomata are slightly raised above the outer surface (Fig. 28). In very old stems the outer and radial walls of the epidermis become very thickly cutinized, the pits in the radial walls are entirely closed (Fig. 29). It is interesting to note that the longitudinal axes of the epidermal cells have a transverse extension⁶ in the stem, as has been described for *Cycacs*, *Encephalartos*, *Tradescantia*, *Crassula*, and many of the *Bromeliaceae* (Fig. 30). As far as the writer has been able to determine, the epidermal cells persist

throughout the entire life of the plant and cork tissue is never formed. Since this appears to be true, as the stems increase in diameter as well as in length, the epidermal cells must necessarily divide (Fig. 30, d). Instead of the openings of the stomata being parallel to the longitudinal axis of the stem, as is the rule in most plants, their longitudinal axes are perpendicular to the longitudinal axis of the stem as is true of *Viscum album*,⁷ *Loranthus*, *Nuytsia*,⁸ *Salicornia*,⁹ *Razoumofskya*, *Casuarina*,¹⁰ and a number of other plants (Fig. 31). The air chambers below the stomata in old stems are almost entirely closed, and the guard cells have lost their chlorophyll and their walls have become cutinized. The cells of the cortex in a young stem are thin-walled and intercellular spaces are usually present (Fig. 27). As the stem increases in size the walls of these cells increase in thickness and become abundantly pitted (Figs. 28 and 32). Numerous groups of stone cells occur toward the inner cortical regions. The outer cells of the cortex contain numerous chloroplasts, while in the inner portion starch is often present in the cell besides crystals of calcium oxalate. The fibro-vascular bundles which are present in the stem are open collateral. Groups of bast fibres are located just outside of the phloëm (Figs. 33, e and 35, a).

THE XYLEM

The first wood elements which are formed are spirally thickened tracheal cells which, later, may form tracheal tubes. Besides tracheal tubes, reticulated and annular tracheids appear as the stem becomes older. Adjacent to the medullary rays and intermingling with the tracheal vessels and the tracheids are thick-walled wood fibres (Fig. 34, b). In describing the formation of the wood fibres of the xylem in *Phoradendron villosum*, Cannon states that they are derived from cells which at first resemble slime cells, and later become changed into wood fibres. In *Phoradendron flavescens* the young cells which later become wood fibres do not resemble the slime cells just mentioned, but their walls gradually become thickened to form wood fibres. In describing the structure of the wood of *Phoradendron villosum*, Cannon states, that there is an abundance of wood parenchyma in the mistletoe as compared with the wood fibres. In *Phoradendron flavescens*

wood parenchyma occurs in very small quantities if present. The wood appears to be made up only of wood fibres, spiral and annular tracheal tubes and annular and reticulated tracheids. On comparing the structure of the woody cylinder with that of a typical woody stem, the wood fibres which contribute so largely to the strength of such a stem are found in small quantities in the mistletoe, while, on the other hand, tracheal and tracheid elements predominate in the wood of the mistletoe and occur in small quantities in a typical woody stem. In the heart-wood of an ordinary woody stem the tracheal and tracheid elements after a time usually lose their function as conducting tissues and become dead cells. In the mistletoe, the same elements seem to function throughout the life of the plant, or, at any rate, for several years.

THE CAMBIUM

In the cambium region, the cells are rather thick walled as compared with the cambium in the stem of the host (Fig. 35). The annular thickening of the stem is so slight, that annular ring formations do not occur, as in a typical woody dicotyledonous stem.

THE PITH

The pith in a very young stem consists of thin-walled parenchyma cells. Very early in the growth of the stem transverse plates of stone cells are formed in the pith. Later, in the development of the stem, the walls of the cells between the plates of stone cells become very much thickened and pitted, and quite irregular in outline (Fig. 36).

THE MEDULLARY RAYS

Like the pith cells, the cells of the medullary rays in the woody portion of the stem are at first thin-walled, but as the stem develops their walls become thicker and abundantly pitted (Fig. 34, a). In the old stems the cells in the outer and inner terminals of the medullary rays contain crystals of calcium oxalate (Fig. 33).

THE HAUSTORIA

The cortical haustoria are formed as a result of the primary haustoria first growing out into the cork cambium. Later, as growth continues, they branch and penetrate somewhat deeper into the cortex of the host, but do not reach the primary cambium. The growth of the cortical haustoria is parallel to that of the aerial branches. In their early development, the haustoria are composed of thin-walled parenchyma cells which contain numerous chloroplasts and a coarse granular substance, which is largely composed of starch. The outer cells on the upper side of the haustoria are very much like epidermal cells in general appearance, while those on the underside are cubical in shape and slightly thinner walled than those above. The outer cells in the advancing tips of the haustoria are often somewhat elongated and papilla-like. These cells are thin-walled, and the nuclei are somewhat larger than in other portions of the haustorium. They are filled with a fine granular protoplasm, and contain numerous chloroplasts (Fig. 37). In general, they resemble the haustorial cells, which have been described by Pierce.¹¹ They are of a glandular character and are called digestive cells, since they secrete a solvent substance which digests most of the cortical cells of the host, so as to make a path for the development and advancement of the haustoria. As described in *Cuscuta*, the digestive cells do not all grow at the same rate, since some are often longer than others. The adjacent cells of the host show evidences of breaking down, and usually there is a small space intervening between them and the digestive cells (Fig. 37). These conditions show that the haustoria do not make their way through the cortex entirely by pressure from growth, but the way for their growth and advancement is opened up largely by the digestive cells secreting a solvent substance which dissolves the cortical cells of the host. The cortical cells of the host in the region which is traversed by the haustoria are usually rich in food materials, which doubtless serve to stimulate them to greater growth and development. Furthermore, the walls of the cells in these regions are rather thin, and naturally more easily dissolved, and consequently furnish a more accessible path for the haustoria. The haustoria in *Phoradendron villosum* have been described as being chemotactic, since they seek the cells richest in food content.

This may be true, but judging from the character of the cortex in *Celtis mississippiensis*, for example, which is a favored host of *Phoradendron flavescens*, and which contains a great number of stone and hard bast cells, the haustoria are forced to follow the path of least resistance since the digestive cells are not capable of dissolving the stone and hard bast cells. Again, in *Phoradendron villosum*, it is claimed that "the form and size of the digestive cells vary with the changes in structure of the host cells. The former are relatively long, when the host tissues furnish them with an abundance of food, but they become short and cubical when the adjacent host cells are poor in food as, for instance, when they are near the surface of the host stem. In the latter case the epithelial cells merge into the more typical epidermal cells. Not only is the shape and size of the epidermal cells dependent on the character of the adjacent host tissue, but it will soon appear that the ramifications of the haustoria through the cortex are also dependent on the same factor, because the epithelial cells make clear the way for advancing haustoria." It is doubtless true that the size of what may be termed strictly digestive cells varies with the food content of the host cells, but it seems that the structure of these cells has very little to do with the form of the digestive cells, since there is nearly always an intervening space between the cortical cells of the host and the digestive cells of the haustoria. In the regions where the "epithelial" (digestive) cells merge into the more typical epidermal cells, they are often in contact with the adjacent cells of the host cortex, as is most always true of the outer cells of the upper and lower sides of the haustoria. It seems, in this case, that pressure from growth within the haustoria is an important factor in determining their shape. As for the ramifications of the haustoria through the cortex of the host, their course is not entirely dependent upon the food content of the cells in the regions traversed, but upon the morphological character of the cells. As already stated, the walls of the cells in that part of the cortex which the haustoria come to occupy are thin and easily digested. Hence they offer the least resistance to the advancing haustoria. Early in the development of the haustoria, a central conducting system is differentiated, while the surrounding cells remain thin-walled and form the cortical region. The cells are rich in chloroplasts, especially in the outer portion

of the cortex and well supplied with starch which becomes more abundant towards the interior. Grit cells are often present, but it is not always possible to determine their origin. They may be formed from cortical cells of the haustoria, or they may be groups of grit cells from the cortex of the host, which have been surrounded and not dissolved by the digestive cells of the haustoria.

SINKERS

The cortical haustoria send out growths from their underside which penetrate the cortex to the cambium layer and later become imbedded in the wood by the formation of new annular rings. These outgrowths are known as the sinkers. Soon after they originate from the haustorium they become directed to the medullary rays of the cortex of the host, which they traverse to the xylem. Later they come to occupy the medullary rays of the wood. The course of the sinkers through the cortex is doubtless influenced by the permeability of the medullary region, and the importance of securing the best relationship for food and water. The structure of the sinkers does not differ essentially from the cortical haustoria. By the time they reach the cambium of the host the cells become slightly heavier walled, while those at the tip of the sinkers are somewhat shortened. The shortening of the cells at the tip is doubtless due to the pressure from growth within. No cells similar in character to the digestive cells of the haustoria were found in the sinkers at any stage of their development. A cross-section through a sinker just below the cambium layer shows two well-defined regions, a central vascular portion, and an outer, or cortical layer (Fig. 38). The structure of a sinker varies according to its position in the host. The part of a sinker which is in the cortical region of the host is very similar to the cortical haustoria, while the portion in the wood has a very different structure. The structure of the central cylinder is the same for both regions of the sinker. The cortical layer of that part of the sinker which is in the cortex of the host is made up of large thin-walled cells and has few intercellular spaces (Fig. 39). The cells are well supplied with chloroplasts and starch. In the xylem of the host the cortical region of the sinker is composed of rather heavy-walled cells, which are abundantly pitted and with no intercellular spaces (Fig. 39).

Starch is sometimes present in the cells in small quantities. Between the two cortical regions of the sinker is a meristematic zone which coincides with the cambium of the host. Here the cells are smaller and slightly thinner-walled than in other portions of the sinker. The vascular tissue of the central cylinder of the sinker is made up of vessels which appear to have both spiral and annular thickenings, and many are reticulated (Fig. 40, v). In *Phoradendron villosum* the tracheary vessels are said to be surrounded with thin-walled elongated cells which are filled with a dense granular substance. If such cells are present in the sinkers of *Phoradendron flavescens*, they were not seen. The tracheids in that part of the sinker which is imbedded in the wood terminate in the cortical cells and are separated from the tracheids in the portion of the sinker which is imbedded in the cortex of the host by the meristematic layer. The tracheids in the latter-named portion of the sinker unite with the same elements in the cortical haustoria which in turn merge into similar tissues in the stem. No sieve tubes are found in the sinkers. The remaining portion of the central cylinder is composed of large, thin-walled, pitted cells with few intercellular spaces (Fig. 40, p). The sinkers are in such close contact with the cells of the host, especially in the wood, that there is apparently a single wall intervening between the cortical cells of the sinker and the adjacent host cells. This association is so intimate, that the pits of the cells in the sinkers are often in direct apposition with the pits of the cells of the host. Thus we see that apparently the most intimate relationship between the mistletoe and its host is in the xylem. Furthermore, as Pierce has shown in the case of *Viscum album*, a special provision is made only in the xylem for the conduction of the substances of the host into the parasite. Since the sinkers are not in direct contact with the phloëm of the host and do not possess sieve tubes, they do not receive freshly elaborated foods from the host, as it is through the sieve tubes that the newly prepared carbohydrates are conducted. Hence the mistletoe is not a total parasite. It is abundantly supplied with chlorophyll both in the leaves and in the stem, and, therefore, in accordance with its relationship to its host, it robs its host largely of water and the mineral salts which chance to be in solution. Thus it is almost entirely a water parasite. Whatever carbohydrate substances are extracted from

the host must necessarily be almost entirely reserve food. Since reserve foods are stored in the xylem, they may be appropriated by the parasite, especially at the beginning of the growing season, when they become liquified for transportation through the xylem to wherever they are needed in the host. The sinkers do not grow down into the wood of the host, but the wood is built up around them. The cells in the meristematic region of the sinkers divide as the cells in the cambium layer of the host divide, so that it is able to accommodate itself to the increase in diameter of the host.

AERIAL HAUSTORIA

Sometimes those portions of the cortical haustoria which are adjacent to the base of the stem of aerial shoots become exposed to the air as a result of their continued growth and the remains of the cortex of the host above disintegrate and weather away. They are known as aerial haustoria, and with their change in environment their structure and function become greatly modified (Fig. 48). The epidermis becomes greatly thickened and colored, and, with the exception of stomata, is very much like the epidermis of an aerial shoot. Cortical and wood cylinder regions are developed, which in general appearance resemble the stem (Figs. 42, c and b). In the cortical region of an aerial haustorium the cells are more or less irregular in size, pitted and contain crystals of calcium oxalate. Clusters of grit cells are often present, as in the cortex of aerial stems. The growth of the woody portion is largely toward the outside of the host. There are no pith and primary vessels present. The wood fibres are formed from slime cells, as Cannon has described in the stem of *Phoradendron villosum*. In describing the structure of aerial haustoria of *Phoradendron villosum*, he states that there is a phloëm region composed of bast parenchyma, sieve tubes and companion cells. If such is true for *Phoradendron flavescens*, it was not recognized. As far as the writer was able to determine, there is a sort of cambium layer between the woody region on the one hand and the cortex on the other. From this cambium zone, there is a gradual transition from very thin walls to thicker walls and pitted cells, as in the cortex of the stem. On the woody side of the cambium, the change from thin-walled cells to woody tissues is abrupt, being quite simi-

lar to an ordinary woody stem. As in *Phoradendron villosum*, there is a marked difference in the proportion of the cortex, and conductive tissue of the cortical haustoria as compared with the same in the aerial haustoria. The amount of cortex is greater in the former, while the conductive tissue predominates in the latter. Starch is present in much larger quantities in the cortex of the cortical haustoria than in the same region in the aerial haustoria. Thus we see that the aerial haustoria come to function as conductive organs and hold-fasts.

THE EFFECT OF THE MISTLETOE UPON ITS HOST

The direct effect of the mistletoe upon its host is an abnormally increased development of tissue in the infected regions, causing them to become greatly distorted and swollen. Pitra¹² has claimed that hypertrophy of the infected portion is caused by an increased flow of sap to this part of the host to supply the demands of the parasite for water. In these regions the proportion of the water vessels to wood fibres and their size is much greater than in normal wood tissue. This condition is evidently caused by excessive flow of sap to meet the needs of the mistletoe for water, and, as growth continues from year to year, the branch becomes heaved out into a large swelling (Figs. 16, v and 49). The effect of the mistletoe upon its hosts, even in the same species, is variable. In some cases the infected regions show very little swelling, while again they are greatly distorted (Figs. 46, and 47). Besides the infected region being hypertrophied by the mistletoe, the part beyond this portion often becomes atrophied as a result of the interception of its water supply, and in time dies. Again, examples have been found where the region below the infected portion of the branch was atrophied, while the part beyond the point of infection had become greatly developed (Fig. 49). As previously stated, the primary haustorium spreads out toward the distal end of the branch, and in many cases gradually encircles it. Thus, in time, the whole circumference of the branch may be surrounded with cortical haustoria, beset with aerial branches and new sinkers sent down into the woody tissue (Fig. 52). Some observers have claimed that the central portion of the branch becomes exhausted and dies as a result of the medullary rays becoming occupied with the sinkers

of the parasite, and at the same time the sinkers in the exhausted regions also die. No such observations were made, where this appeared to be true as a result of the direct effect of the mistletoe. A number of examples were found in which the tissues of the host in the region of the sinkers had begun to decay, as well as the sinkers themselves. In these cases, the mistletoe had been attacked by wood-boring insects which made large excavations in the basal portion of the plant in the cortical region of the host (Fig. 50). As a result, the aerial branches with the adjacent cortical portions of the mistletoe are often killed. Thus in the destruction of the parasite ways are opened by means of which insects, fungi and bacteria gain entrance to the host. Many believe that mistletoe actually kills trees. If this be true, it has never been observed by the writer. There can be no doubt that the mistletoe does greatly stunt or affect the growth of trees, often causing them to be dwarfed, and their branches greatly distorted (Figs. 53, 54, and 55). As previously stated, in many cases the portion of the branches beyond the infected regions die. This is frequently due, especially in young branches and twigs, to the direct effect of the mistletoe. As stated above, the mistletoe itself may often be killed by being attacked by wood-boring insects. Thereby ways are opened up so that fungi, bacteria and insects gain entrance into the branches, which in time die. Another apparent effect may be seen in examples of badly infected trees that are often delayed for several days in putting out their leaves. Here we must take into consideration the fact, that normal trees of the same species growing in the same vicinity do not always send forth their leaves at the same time. Observations were made where the leaves in badly infested trees were at least two weeks late in making their appearance. Is the relationship of the mistletoe and its host a mutual advantage, or does the mistletoe receive all the profits at the expense of its host? Bonnier¹³ has pointed out that *Viscum album* during the summer is nourished by its host, and during the winter it in turn furnishes its host with food. It does not seem probable that such harmony as just mentioned between host and parasite prevails in the case of *Phoradendron flavescens* and its host. During the winter trees are in a state of rest, and there is very little, if any, demand for food. The structure of the mistletoe itself is such that there can be little possibility of

any food transference from it to its host. Many examinations were made of material collected from December to the middle of March, for the purpose of determining whether there was any difference in the content of the food storage cells of the mistletoe and adjacent cells in the host; but none could be detected. Furthermore, the food content in these adjacent tissues of the host was identical to that of similar tissues of uninfected parts. The only difference, if any, was that in the former the cells seemed to be more densely filled with starch than in the case of the latter. It was also found that the starch grains present in the cortical cells of the sinkers were almost identical in shape and size to those of the adjacent host cells.

It has been claimed that *Phoradendron villosum* is totally parasitic during its younger stages upon its host. In *Phoradendron flavescens* there appears to be no period in which it is wholly parasitic. Until the young plant has penetrated into the cork cambium of its host, it is entirely dependent for its food supply upon the endosperm, which not only contains stored food, but a photosynthetic mechanism to supply the further demands of the young plant. Even when the young plant has become established, it is probable that it does not draw entirely upon its host for food, since its own cells are rich in chlorophyll. It is impossible to determine the extent of parasitism in the mistletoe. As has already been shown, it is largely a water parasite. A number of experiments were tried with the purpose of testing the extent of its water parasitism, by cutting away the outer cortical layers of the host immediately surrounding the bases of aerial shoots, so as to remove the greater portion of the cortical haustoria. These experiments were begun about January 15, 1908, and the plants were alive and apparently thriving as well as those growing under normal conditions on May 20, 1908. No observations were made again until October 1, 1908, when the plants were found to be dead. Even if the plants had lived, there would not have been sufficient evidence to prove that the mistletoe is a water parasite. Neither did the failure to live prove that it is not a water parasite. But since the plants died, it seems we have more ground for believing that the mistletoe is not so much a water parasite as has been believed, but is dependent upon its host for a portion of its carbohydrate food.

In structure, the mistletoe is typically xerophytic. It is not

possible to determine what the factors are which have brought about this structure. The very nature of the habitat of the mistletoe is doubtless the important factor in producing its characteristic structure. Not being in direct contact with soil water, the mistletoe is forced to obtain its water second-handed from the tree. The host itself passes through a period of seasonal drought each year, which occurs in the winter months. In this vicinity it sometimes happens that there is very little rainfall, if any, from the middle of June to the latter part of September. During the first period mentioned, the flow of sap is practically at a standstill, while in the latter example the sap flows exceedingly slow. As a result, there are times when the mistletoe is able to secure very little water from its host. Such conditions have contributed very largely in bringing about a xerophytic structure, especially in producing such adaptations as water storage reservoirs in the leaves.

The trees that are most subject to infection by *Phoradendron flavescens* in this vicinity are mesquite, hackberry, elm, osage orange and various oaks. In Austin fully ninety per cent of the trees subject to mistletoe are infected. Trees are often so densely infected with mistletoe that they present a leaved appearance during the winter months of the year (Fig. 56). Mistletoe has been observed growing on the following named trees: hackberry, elm, mesquite, oak (excepting live oak), ash, osage orange, prickly ash, pecan, gum elastic, *Foresteria*, walnut, mulberry and wild china berry. Of the trees just mentioned, the hackberry, elm and osage orange are the most favored hosts of the mistletoe in the vicinity of Austin. Of these, the osage orange becomes most greatly distorted. Why some trees are infected more than others has not been definitely determined, but the reason is doubtless due to the fact that in such trees as hackberry, for example, the branches, and especially the twigs, are covered by a very thin layer of corky tissue. Hence in such cases the outer cortical tissues are more easily and quickly penetrated than they would otherwise be. Apparently a number of different species of trees are totally immune to mistletoe. The cause of immunity is not definitely known. It is most likely due to the nature and structure of the bark, and the chemical contents of the cortical cells beneath. It seems that this is the only way to account for the absence of mistletoe upon

such trees as the box elder, willow, sycamore and china tree. A number of attempts were made to grow mistletoe upon the china tree, but all failed. There is in the younger portions of the tree a periderm-like covering through which the embryos could not penetrate. That immunity may be partly due to the chemical contents of the cortical cells, is only a theory, since the writer has never observed examples where the seedlings had penetrated the outer cork layer, and then perished. Again, in such trees as the cottonwood immunity may be largely due to the thickness of the outer corky layer. Hence, we might conclude that the chief factors in immunity of certain trees to *Phoradendron flavescens* are the character of the external surface and the thickness of the outer layers of cork.

REMEDIES AND MEANS OF ERADICATION

Very little has ever been done in this State towards the extermination of the mistletoe. This is doubtless due to the fact that no means for destroying it without injury to its host is known. The present method for removing the mistletoe from trees in this vicinity is by the use of a long pruning hook, or "breaking it out" of the tree by some other means (Fig. 57). By such methods of pruning, if done before the berries mature, the further dissemination of the mistletoe will be prevented if continued by the universal co-operation of all real estate owners.

It has been claimed that by continued pruning from year to year after a time the plant will die. According to statements made by reliable citizens whose observations extend over a period of ten years or more, the haustoria do not seem even hindered in their growth by the yearly pruning of the aerial shoots, and at the beginning of every season send up new shoots. The writer has observed that a number of real estate owners in this vicinity have endeavored to kill the haustoria by painting the infected regions with various creosote preparations, but all of these attempts at killing the mistletoe have failed.

The writer has a number of experiments in progress in order to find a means for killing the mistletoe without injury to the host. These experiments were begun January 22, 1908, and thus far, with few exceptions, have been successful. The method employed is as follows: The aerial shoots were first cut out and then the

outer layers of cork in the infected regions were shaved off with an ordinary drawing knife, so as to expose the entire haustorial portion of the plant. Then these portions were thoroughly coated with coal tar, in order to prevent further development of the haustoria, and to keep out fungi and insects. If this method does not prove entirely successful, it will, at any rate, greatly retard further development of the mistletoe, and, though it may seem laborious, a valuable tree is always worth saving. In ridding trees of mistletoe, the smaller branches which are parasitised should be pruned out, while the larger infected regions should be treated as stated above.

SUMMARY AND CONCLUSION

The dissemination of the mistletoe is almost entirely by birds.

It is a slow grower. Its maximum period of growth coincides with that of its host, and growth apparently continues throughout the entire summer.

The mistletoe is not a total parasite. Since it is so abundantly supplied with chlorophyll, both in the aerial shoots and in the haustoria, it is not entirely dependent upon its host for carbohydrate food substances. Its relationship to its host is such that it is largely a water parasite, and whatever carbohydrate substances it takes from its host are reserve foods, which have been stored in the wood.

In structure it is essentially xerophytic.

The most favored hosts of the mistletoe in this vicinity are hackberry, elm, mesquite and osage orange.

The immunity of certain trees to the mistletoe is largely due to the character of the external surface and thickness of the outer corky layer.

The direct effect of the mistletoe upon trees does not kill them, but often causes them to become very much dwarfed, and their branches greatly distorted. Parts of trees, or whole trees, may die as an indirect result of being infected with mistletoe. The mistletoe is first killed by wood-boring insects, and then through it ways are opened by which fungi, bacteria and wood-boring insects gain admittance to the trees, which in turn die from the effects of these pests.

If properly treated, the mistletoe can be killed without injuring the host.

This study was begun in the winter of 1906-1907 and was carried on in the Laboratory of the School of Botany at the University of Texas. The observations made in this investigation are limited almost entirely to the mistletoe as seen in the vicinity of Austin, Texas. The writer takes pleasure in expressing his gratitude for the advice and suggestions given by Dr. F. D. Heald, Professor of Botany at the University of Texas, and the kind assistance of Mrs. Edith C. York in making the drawings.

LITERATURE CITED

1. Cannon, W. A. Observations on the germination of *Phoradendron villosum* and *P. californicum*. Bull. Torr. Bot. Club, 31:435-443. 1904.
2. Kerner and Oliver. Natural History of Plants, 1:210. 1895.
3. Cannon, W. A. Anatomy of *Phoradendron villosum*. Nutt. Bull. Torr. Bot. Club, 28:374-390. 1901.
4. Marktanner-Turneretscher. Sitzungs d. k. Akad. d. Wissen. Math.-natur. Classe, Wien, 91:5 Heft. 1885.
5. Solereder. Anatomie der Dicotyledonen. 1899.
6. De Bary. Comparative Anatomy of Phanerogams and Ferns, p. 31. 1884.
7. Von Mohl. Bot. Zeit., 1849. Tab. 9.
8. Chatin. Anatomie comparée des Végétaux, Plantes parasites, Tab. 80, 82.
9. Duval-Jouve Bul. de la Soc. Bot. de France, 15:139. 1868.
10. Loew, de *Casuarinearum caulis folique evolution et structura*, p. 35.
11. Pierce, George J. On the Structure of the Haustoria of Some Phanerogamic Parasites. Ann. Bot., 7:291-326. 1893.
12. Pitra, A. Ueber die Anheftungsweise einiger Phanerogamen Parasiten an ihre Nahrpflanzen. Bot. Zeit., 19:1861.
13. Bonnier, Gaston. Sur l'assimilation des plantes parasites a chlorophyll, Comptes Rendus, 113:1074-1076. 1891.

EXPLANATION OF PLATES

An Abbe camera was used in making the drawings, and with the exception of Figs. 7, 8, 9, 10, 12, 14, 15, 22 and 26, they were made from free-hand sections of fresh material. Figs. 6, 7, 8, 9, 12, 14, 15 and 16, were drawn with a Bausch and Lomb dissecting microscope and a one-inch lense. With the exception of No. 7, which is enlarged about 4.7x, they have a magnification of 2.5x.

The remainder of the drawings were made with a Leitz Com-

pound Microscope, and are magnified as follows: Figs. 1, 2, 10, 13, 22, 33, 38, 41, and 42, 10.5x; Fig. 11, 21x; Figs. 3, 17, 18, 24, 25, 34, 35 and 39, 77x; Figs. 20, 21, 23, 27, 28, 29, 30, 31 and 37, 109.3x; Figs. 4, 5, 19, 32 and 36, 203.7x; Figs. 7 and 8 were made by Miss Nannie Lea Caldwell, formerly student assistant in Botany. Fig. 57 was photographed by Dr. W. L. Bray, Professor of Botany, Syracuse University.

•
PLATE I

Fig. 1 Section of mature seed, showing embryo, endosperm and testa: d, region of endosperm containing chlorophyll.

Fig. 2 Cross section through seed in region of cotyledons, a.

Fig. 3 Section through endosperm in the region of cotyledons; a, outer layer of cells of cotyledons; b, external layer of cells in the endosperm; c, testa.

Fig. 4 Cells from the outer layer of cells of the cotyledons as seen in a, Fig. 3.

Fig. 5 Cell from radicle of the embryo.

Fig. 6 Mature berry: a, seed; b, viscin; c, outer coat.

Fig. 7 Seedling showing attachment disc, a; b, hypocotyl; c, seed.

Fig. 8 Lateral view of seedling showing attachment disc, a; b, primary haustorium; c, remains of seed.

Fig. 9 Two embryos from a single seed showing attachment discs.

Fig. 10 A one-year-old plant: a, primary haustorium; b, cork cambium; c, primary cambium; d, seed.

Fig. 11 A plant one-year old showing first sinker, b; a, primary haustorium; c, cork cambium; d, primary cambium; e, medullary rays occupied by the sinker.

Fig. 12 A plant three years of age: a, remains of seed; b, cotyledons; c, bud on the attachment disc.

Fig. 13 A plant two years old, in which foliage leaves have not appeared: a, an aerial shoot-bud on the attachment disc; b, cortical haustorium; c, primary cambium; d, annual ring of the xylem.

Fig. 14 A plant two years of age, showing the first pair of foliage leaves: a, old hypocotyl; b, remains of endosperm.

PLATE II

Fig. 15 A plant which was about four years old: a, old hypocotyl.

Fig. 16 A plant which is three years of age with but a single pair of foliage leaves. The sinkers are imbedded in two annual rings, and the old hypocotyl is still present: a, cortex of host; v, inner portion of annual rings showing water vessels.

Fig. 17 Section of a very young leaf.

Fig. 18 Section of an old leaf.

Fig. 19 Cell from the outer mesophyll region of a mature leaf showing chloroplasts, nucleus and pitted character of the cells; a, portion of the wall showing peripheral layer of cytoplasm and chloroplasts.

Fig. 20 Cross section of a stoma from a mature leaf.

Fig. 21 Surface view of a stoma from a mature leaf.

Fig. 22 Surface view of a portion of a leaf that had been cleared in chloral hydrate, showing water reservoirs, and their relationship to the veins.

Fig. 23 Section through a water reservoir showing relationship to a vein: a, water tracheids; b, tracheal cells; c, stratified layers of mucilage in cells which are changing to form water storage cells; d, chloroplasts in outer region of the cell.

Figs. 24 and 25. Sections through water storage reservoirs showing calcium oxalate crystals, e, in surrounding cells.

PLATE III

Fig. 26 Surface view of leaf that had been cleared in chloral hydrate, showing general distribution of the water reservoirs.

Fig. 27 Longitudinal section from outer cortex of a very young stem, showing a cross section of a stoma.

Fig. 28 Longitudinal section from outer cortex of an old stem, showing a cross section of a stoma.

Fig. 29 Epidermis from a very old stem.

Fig. 30 Surface section of the epidermis from a stem: d, a cell which has just divided.

Fig. 31 Surface view of stoma from the stem.

Fig. 32 Cell from cortex of an old stem.

Fig. 33 Cross section of a stem: a, medullary rays; b, wood

fibers of the xylem; c, water vessels; d, pith; e, bast fibres; i, phloem; f, cambium zone; g, grit cells.

Fig. 34 A portion of the xylem: a, medullary rays; b, wood fibres; c, water vessels.

Fig. 35 The phloem region: a, bast fibres outside of the phloem; b, cambium zone.

Fig. 36 A pith cell.

Fig. 37 Cells from the advancing point of the haustorium: c, cortical cells of the host.

Fig. 38 Cross section of a sinker just beneath the primary cambium: a, cortical region; b, central vascular region.

PLATE IV

Fig. 39 Longitudinal section through the outer cortical regions of a sinker: m, meristematic zone of sinker; c, cells from the primary cambium of the host.

Fig. 40 Longitudinal section of a portion of the sinker which is imbedded in the xylem: b, medullary ray cells of host; c, cortical cells of sinker; v, vascular tissue; p, pitted parenchyma of the central cylinder.

Fig. 41 Longitudinal section of a sinker: c, cortex; v, vascular strands; p, parenchyma cells.

Fig. 42 Cross section of an aerial haustorium: c, cortical region; b, central cylinder of woody and vascular tissue; v, vascular strands; w, wood fibres; m, meristematic zone; g, grit cells.

Figs. 43, 44, 45 Plants about five, six and seven years of age.

PLATE V

Fig. 46 A plant three feet in length, about twenty years of age, and showing a slight hypertrophy in branch of the host.

Fig. 47 A typical growth of *Phoradendron flavescens*. The plants were about two feet in height.

PLATE VI

Fig. 48 Basal portion of a plant showing aerial haustoria, a.

Fig. 49 A branch of *Acacia*, which is atrophied below and hypertrophied above the infected region.

PLATE VII

Fig. 50 Basal portion of an aerial shoot which was almost entirely eaten out by ants that had gained entrance into the mistletoe as the result of wood-boring insects.

Fig 51 Aerial shoots one year old, which developed from stumps of aerial shoots, which had been broken off in the preceding year.

PLATE VIII

Fig. 52 A cross section of the branch represented in Fig. 49, showing how the haustoria encircles the branch and position of sinkers and aerial branches.

PLATE IX

Fig. 53 A distorted limb from mulberry.

PLATE X

Fig. 54 Osage orange, the limbs of which are greatly distorted as the result of the mistletoe.

PLATE XI

Fig. 55 An elm showing the dwarfed and distorted condition of the limbs caused by the mistletoe.

PLATE XII

Fig. 56 A hackberry tree, *Celtis mississippiensis* badly infested with *Phoradendron flavescens*.

PLATE XIII

Fig. 57 The ordinary way of pruning mistletoe from trees.

PLATE I

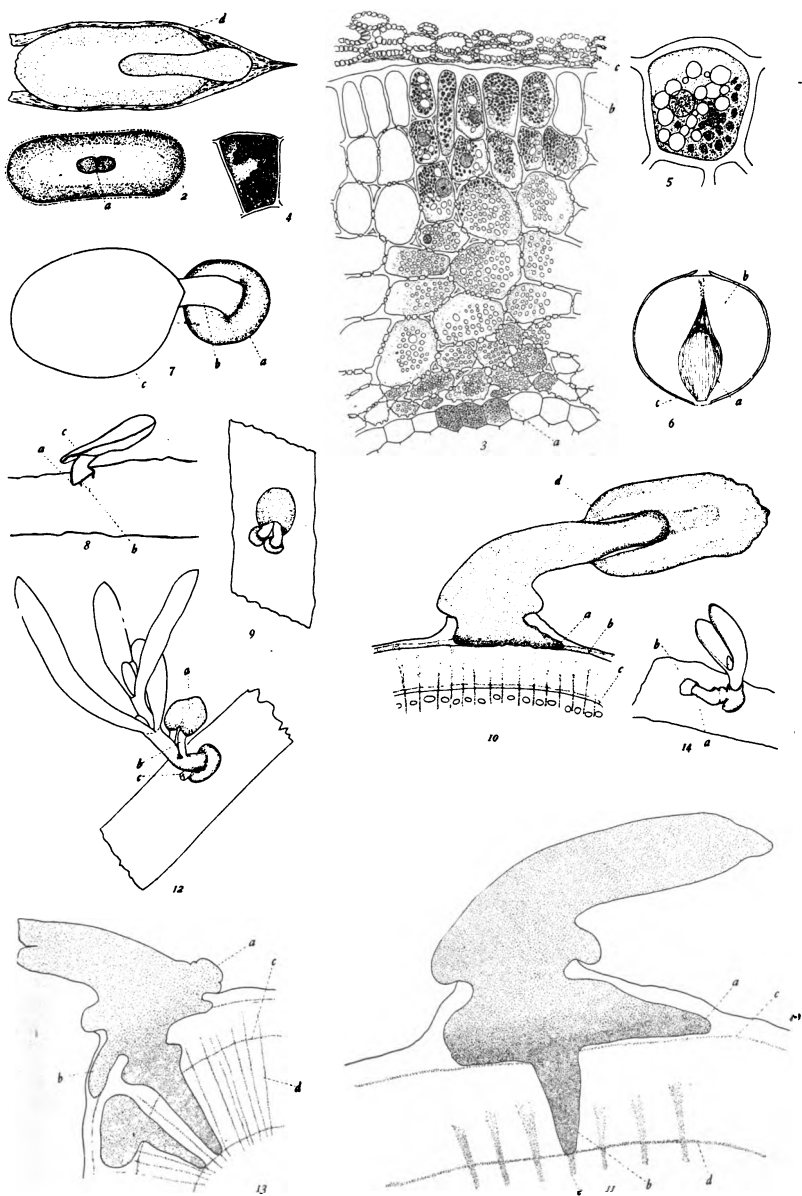


PLATE II

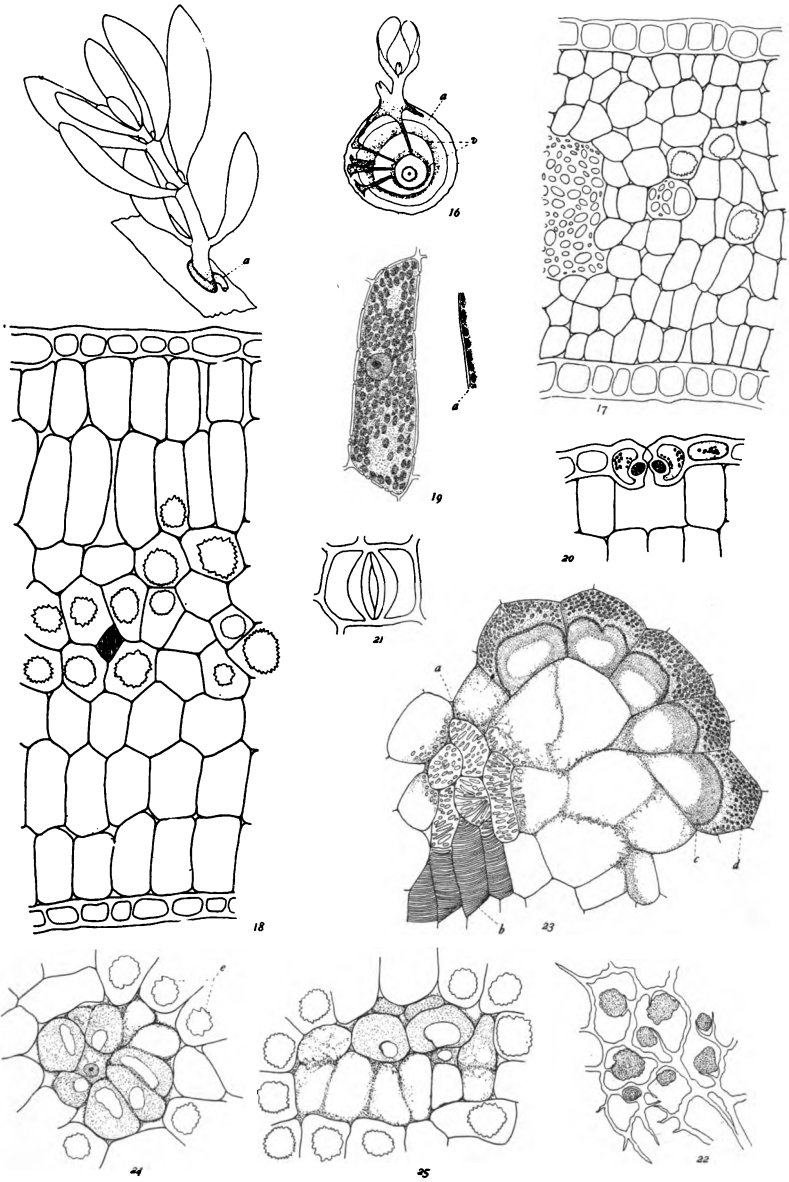


PLATE III

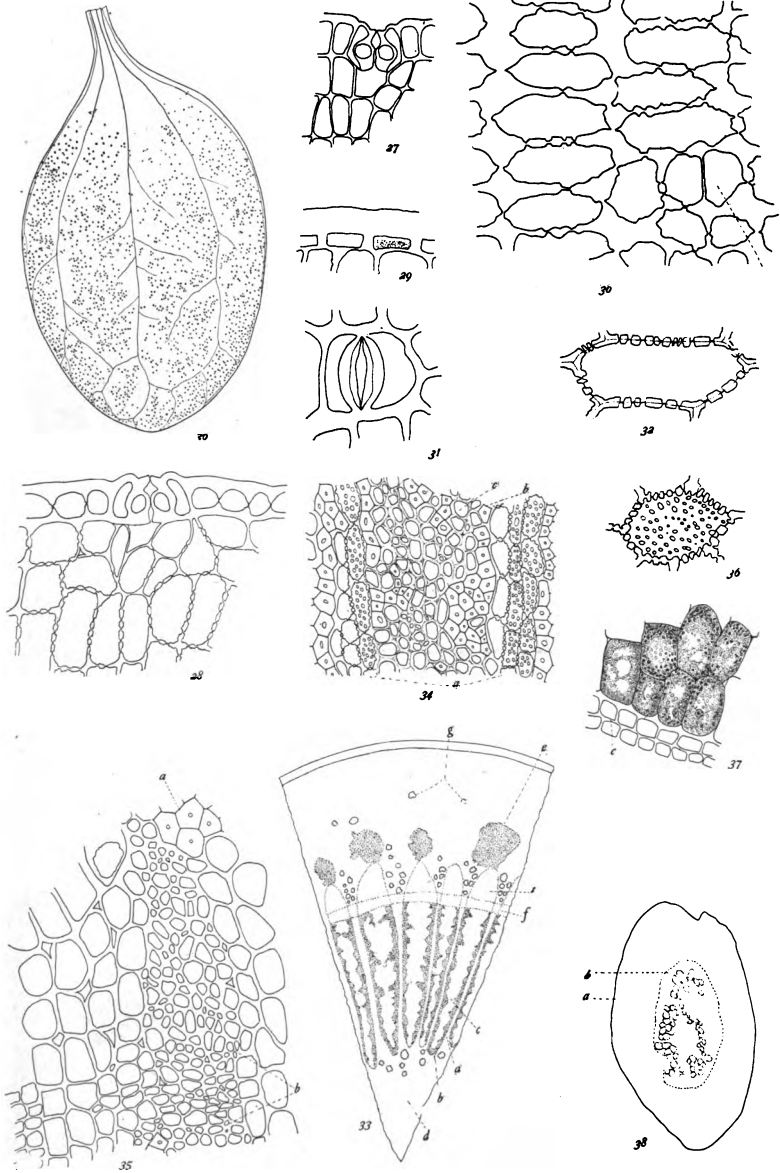
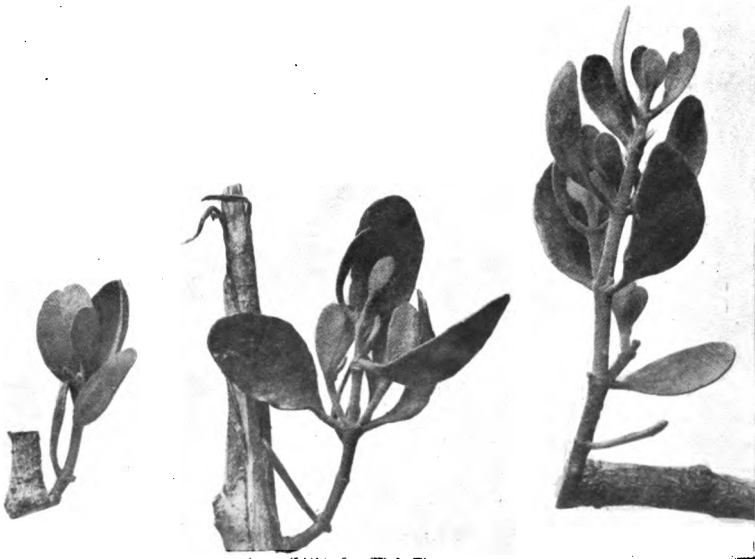
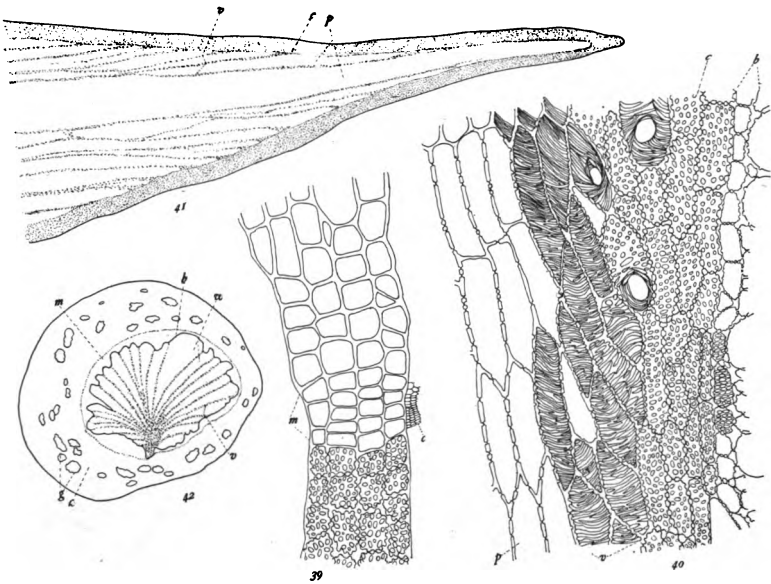
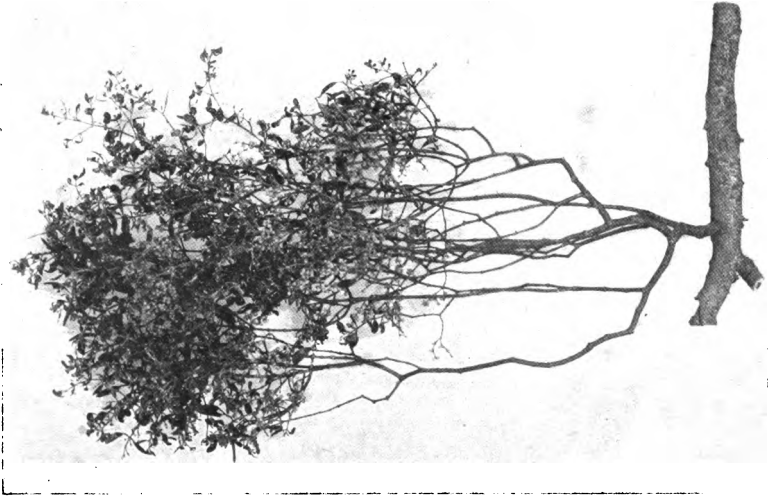


PLATE IV



43, 44, 45. Plants About Five, Six and Seven Years of Age.

PLATE V

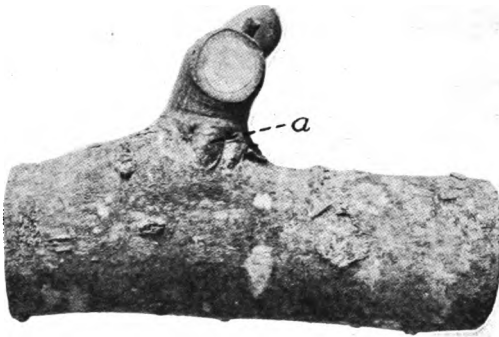


46. A Plant Which Was Three Feet in Length and about Twenty Years of Age.



47. A Typical Growth of *Phoradendron Flavesces* about Two Feet in Height.

PLATE VI

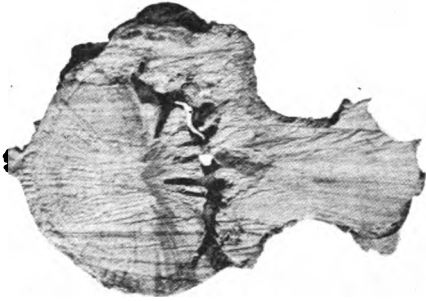


48. Basal Portion of a Plant Showing Aerial Haustorium, a.



49. Branch of *Acacia* Atrophied Below and Hypertrophied Above the Infected Region.

PLATE VII



50. Basal Portion of an Aerial Shoot which was almost Eaten out by Ants.



51. Aerial Shoots One Year Old Which Developed from Stumps of Aerial Shoots Which Were Broken off in the Preceding Year.

PLATE VIII



52. Cross Section of Branch Represented in Fig. 49, Showing How the Haustoria Encircle the Branch and the Position of the Sinkers and Aerial Braches.

PLATE IX



53. Distorted Branch of Mulberry Caused by Mistletoe.

PLATE X



54. Osage Orange, the Limbs of which are Greatly Distorted as the Result of Mistletoe.

PLATE_XI



55. Elm Showing the Dwarfed and Distorted Condition of the Limbs Caused by Mistletoe.

PLATE XII



56. Hackberry Badly Infected with Mistletoe.



57. The Ordinary Way of Pruning Mistletoe Out of Trees.

THE UNIVERSITY OF TEXAS BULLETIN

GENERAL SERIES

- 1, 6, 12, and 14 were numbers of *The University of Texas Record*.
2. *Alumni Notes*. 13 p., March, 1904.
3. *Some Wholesome Educational Statistics*, by W. S. Sutton. 12 p., illus. March, 1904. 10 cents.
4. *Courses of Study in Law Pursued in the University of Texas*, by J. C. Townes. 16 p. March, 1904. Out of print.
5. *Notes Concerning the Progress of the University of Texas*, by Wilson Williams, Registrar. 3 p., 1904. Out of print.
7. *The Consolidation of Rural Schools*, by Una Bedichek and G. T. Baskett. New edition, enlarged by A. C. Ellis. 85 p., illus. November, 1907. 25 cents.
8. *The Pride of Texans and Their University*, by T. H. Montgomery, Jr. 5 p. November, 1904. Out of print.
9. *Letter to Alumni Regarding the Proposed Law School Building*. 2 p. December, 1904. Out of print.
10. *Views of the University of Texas*. 42 p., illus., n. d. 20 cents.
11. *What Should be Done by Universities to Foster the Professional Education of Teachers?* by W. S. Sutton. 24 p. 1905. 15 cents.
13. *School Buildings*, by A. C. Ellis and Hugo Kuehne. 119 p., illus. pl. June, 1905. 30 cents.
15. *The Teaching of Agriculture in the Public Schools*, by A. C. Ellis. 56 p., illus. December, 1906. 25 cents. Out of print.
16. *A Study in School Supervision*, by Carl Hartman. 180 p. 1907. 50 cents.

HUMANISTIC SERIES

1. *The Trans-Isthmian Canal: a Study in American Diplomatic History (1825-1904)*, by C. H. Huberich. 31 p. March, 1904. 25 cents. Out of print.
2. *The Evolution of "Causa" in the Contractual Obligations of the Civil Law*, by Samuel Peterson. 24 p. January, 1905. 25 cents. Out of print.
3. *De Witt's Colony*, by Ethel Z. Rather. 99 p., 4 maps. 1905. 35 cents.
4. *Some Fundamental Political Principles Applied to Municipal Government*, by Samuel Peterson; and *Evans Prize Orations*. 39 p. June, 1905. 15 cents.
5. *The Grotesque in the Poetry of Robert Browning*, by Lily B. Campbell. 41 p. April, 1907. 25 cents.
6. *The Beginnings of Texas*, by R. C. Clark. 94 p., map. December, 1907, 75 cents.
7. *Railroad Transportation in Texas*, by C. S. Potts. In press.

MEDICAL SERIES

1. *Yellow Fever: a Popular Lecture*, by James Carroll. 32 p. June, 1905. 15 cents.
2. *The Care of the Insane*, by Dr. M. L. Graves. 16 p. 1905. 15 cents.
3. *The 1903 Epidemic of Yellow Fever in Texas, and the Lesson to be Learned from it*, by Dr. G. R. Tabor. 22 p. June, 1905. 15 cents.

THE UNIVERSITY OF TEXAS BULLETIN

SCIENTIFIC SERIES

- 1-4. *Contributions from Zoological Laboratory of the University of Texas.* Reprints from various journals. 1904-05. Out of print. Later contributions appear in the Reprint Series.
5. *Test of a Vertical Triple Expansion High-Duty Pumping Engine in Operation at the Water Works, San Antonio, Texas*, by A. C. Scott. 52 p., illus. pl. June, 1905. 35 cents.
6. *Vegetation in the Sotol Country in Texas*, by W. L. Bray. 24 p., pl. June, 1905. 25 cents.
7. *Observations on the Habits of Some Solitary Wasps of Texas*, by Carl Hartman. 72 p., pl. July, 1905. 25 cents.
8. *The Protection of Our Native Birds*, by T. H. Montgomery, Jr. 30 p. October, 1906. 25 cents.
9. *The Austin Electric Railway System*, by members of the Senior Class in Electrical Engineering, 1906. 123 p., illus. pl. 1906. 50 cents.
10. *Distribution and Adaptation of the Vegetation of Texas*, by W. L. Bray, 108 p., pl. map. November, 1906. 35 cents.
11. *A Sketch of the Geology of the Chisos Country*, by J. A. Udden. 101 p. April, 1907. 50 cents.
12. *The Clays of Texas*, by Heinrich Ries, 316 p., illus. pl. 1908. \$2.00.
13. *The American Mistletoe*, by H. H. York. 31 p., pl. 1909. 50 cents.

REPRINT SERIES

1. *A Semantic Study of the Indo-Iranian Nasal Verbs*, by E. W. Fay. From the American Journal of Philology, 25:369-389 and 26:172-203, 377-408. March, 1906. Out of print.
2. *Contributions from the Zoological Laboratory of the University of Texas.* From various journals. May, 1906. Out of print.
3. *Latin, Greek, and Sanskrit Word Studies*, by E. W. Fay. From various journals. November, 1907. Out of print.
4. *Spelling and Arithmetic*, by C. Yeidel. From the Southern Educational Review, October-November, 1907. 8 p. 10 cents.
5. *On Sundry Confixes*, by E. W. Fay. From the Amer. Jour. of Philol., 28:411-418. March, 1908. Out of print.
6. *The University and the State*, by T. W. Gregory, from the University of Texas Record, 1908, 8:297-310.
7. *The Incidental Teaching of English*, by Morgan Callaway, Jr., from the University of Texas Record, 1909, 9:33-45. 15 cents.
8. *A Word-List from East Alabama*, by L. W. Payne, Jr., from Dialect Notes, 1908-09, 3:279-328, 343-391. 50 cents.

In addition to the bulletins named above are the following:

- a. The Official Series, which includes catalogues, Regents' Reports, and administrative bulletins.
- b. About 25 bulletins issued before March, 1904, when the division into series began.
- c. *The University of Texas Record*, formerly, but no longer, included in the General Series. Numbers of the *Record* have been issued from two to four times a year since December, 1898, and it is now in its 9th volume. It is of special interest to alumni, ex-students, and friends of the University, and will be mailed regularly to any one who requests it.

Requests for Bulletins should be addressed to the University of Texas Bulletin, Austin, Texas. Exchanges should be addressed to the University of Texas Library.

